Computer Simulation of Sand Ripple Growth and Migration

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LONG-TERM GOALS

The long-term goals of this study are to improve our understanding and ability to predict sand ripple size and migration under conditions relevant for active mine burial. The principal product from this study will be a computer simulation type model of sand ripple growth and migration in which the effects of waves and currents can be simulated. In fine to medium sand scour-type bedforms grow to meter scale horizontal dimensions and 0.1-0.4 meter scale vertical dimensions under storm waves. There are many potentially dominant variables controlling bedform size, shape, and migration rate, including wave orbital diameter, period, current strength, bed sediment size, size distribution, and compaction. Computer simulation has the potential to assist in understanding which of these variables are dominant under a variety of conditions. The potential improvement in the understanding of the fundamental mechanisms of sand bedform formation from this study will be a significant contribution to the quantification of bedform processes related to the burial of mines in sandy coastal environments.

OBJECTIVES

The objectives of this project are to modify, calibrate, and combine recently developed computer simulations of sand ripple growth and movement to make them applicable to the computer simulation of mine burial. The computer simulation work includes modifying and expanding the computer model of Wilson 1996 and interfacing it with the models of Wiberg and Smith 1985 and Rubin and Hunter 1987. The Wilson model is a highly nonlinear coarse-grid simulation that captures the relevant sediment transport physics in semi-empirical parameterizations from the Coastal Engineering and wave-flume literature. The Wiberg-Smith model can help to determine the transport effects of bed slopes which are difficult to measure experimentally. The Rubin-Hunter model incorporates directionality in the forcing in the result of migration of the ripples (but requires other bedform characteristics such as height as inputs). This model has the potential to predict results of bedforms with complex formation histories under changing conditions.

APPROACH

The approach can be summarized in the following list of tasks as follows:

1. Add a Bagnold-type gravitational settling term to the model to enhance prediction capability. The model currently has an oversimplified gravitational term, a more realistic version will lead to the model converging more quickly and possibly stabilizing on a more accurate bedform size.

2. Enhance the model of Wilson 1996 to include grain size effects. This task involves recalculating mobility and gravitational settling parameters for a variety of sand sizes. The model will then be run through a range of wave and current conditions for each sand grain size.

3. Perform computer model sensitivity studies to identify parameters that need further measurement. Several terms in the model are not well characterized in either flume or field experiments, their sensitivity in the model must be checked over a range of forcing conditions and sand grain sizes.

4. Interface this improved model to the Wiberg-Smith model and Rubin-Hunter model. One way to enhance trust in the model is to demonstrate that it produces the same results as other models in similar parameter ranges if these ranges can overlap.

WORK COMPLETED

Task 1, addition of a Bagnold-type gravitational settling term to the model has been implemented and tested.

Task 2, The enhancement of the Wilson 1996 model to include grain size effects has been implemented and testing is underway.

Task 3, the model sensitivity analysis to these additions has been automated using a new graphical user interface. This new graphical user interface (Figure 1) allows control over a variety of parameters, and facilitates automatic recording of parameters and the run results from those parameters. Also new is the capability to run a simulation from a previous final bed state and the ability to alter the wave-current conditions interactively during a run (to simulate progressive bed armoring, for example).

Task 4, the interface to other models has been facilitated by an extensive rewrite of the code structure. This rewrite made various functions modular, made scripts into functions with well defined input and outputs, and increased efficiency by allowing certain portions of code to be translated from MATLAB into C++ .

RESULTS

The implementation of a gravitational settling term to the Wilson 1996 model gave very encouraging results. Small amount of preferential settling of suspended sand into the troughs of ripples did not affect ripple growth or migration, but in certain conditions led to stable bedforms where previously there had only been transient forms. It is now clear that a 'bedload only' style model needs gravitaional terms in addition to trajectory to generate realistic bedforms, especially under more energetic conditions.

Several bedload formulas from the literature were tested. The model was not found to be particularly sensitive to which form was used. The Meyer-Peter and Mueller formula was adopted for general comparison with other experimental and theoretical results. There is potential for multi-size modeling, in which the model would be much more sensitive to the specifics of size dependence. While the lack of sensitivity to bedload formulation was an expected result, it was also a very reassuring result.

The final state of the bed for a given set of wave-current and sedimentological parameters appears to depend partly on the previous state of the bed in both field and model results. Adding initial condition of the bed as an input parameter to the model increases the complexity of compiling, comparing, and presenting results.

The restructuring of the program into modular units has made model verification and validation testing a much more straightforward process. Additional adjustable parameters may be added in a structured manner, with minimum modification of existing code. Figure 1 shows the graphical user interface for the model. The current model output is still a two-dimensional array in which bed height is proportional to a gray scale. A blue arrow in one corner denotes wave direction, and the red line shows a profile cross-section in the approximate location of the graphical data, with an expanded vertical scale. Work is ongoing to condense and summarize this data further, into a bed roughness length and height scale, for example, in a statistically optimal way.

IMPACT/APPLICATIONS

The potential improvement in the understanding of the fundamental mechanisms of sand bedform formation from this study will be a significant contribution to the quantification of bedform processes related to the burial of mines in sandy coastal environments.

TRANSITIONS

This work is still relatively new, so this author is not aware of existing transitions. The potential exists to include this model into a community sediment transport or mine burial model.

RELATED PROJECTS

This project is closely related to the mine burial initiative field experiment of Dr. Peter Howd. This field experiment will provide important ground truth and calibration data.

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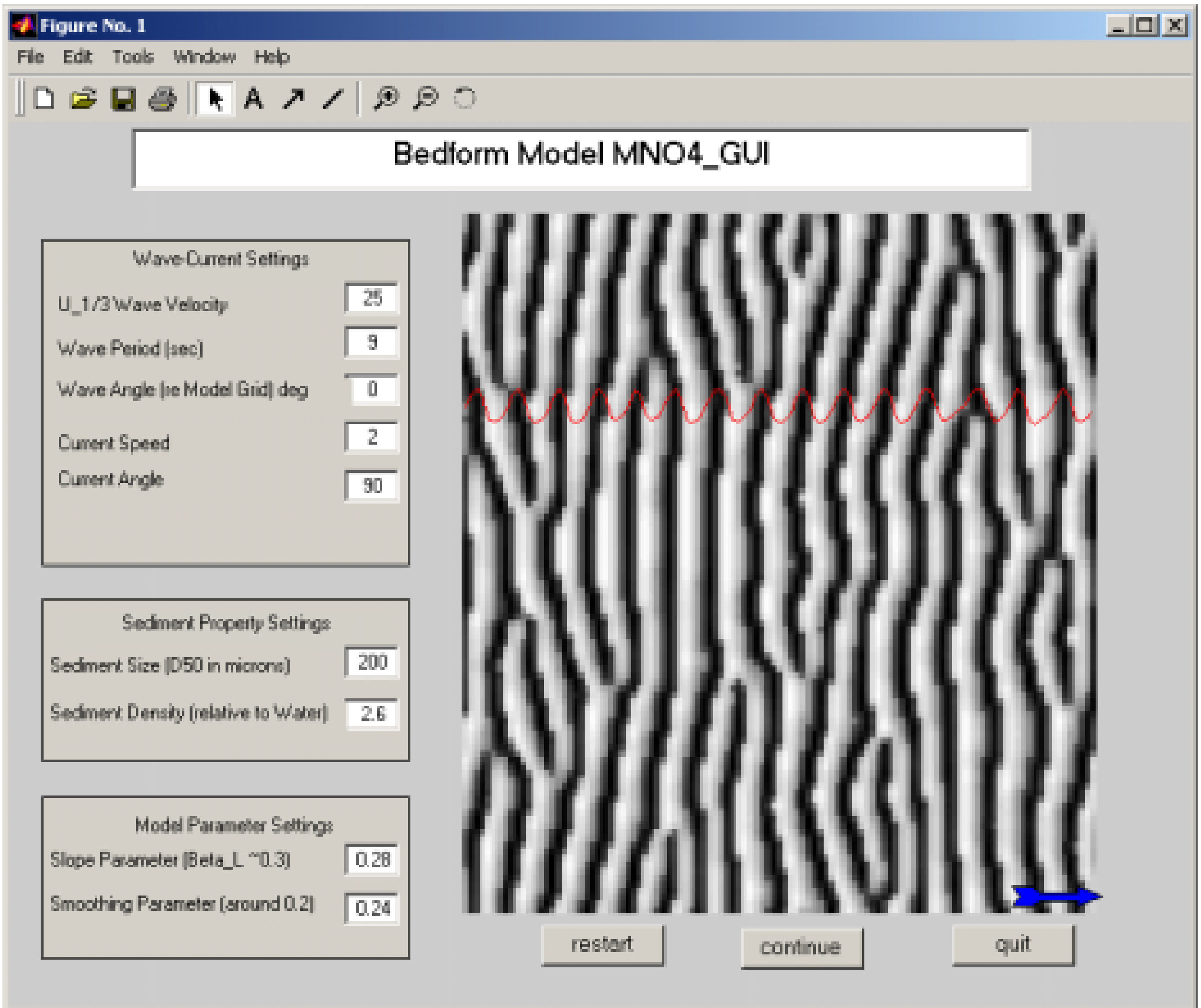

Figure 1: Screen capture of Bedform Model graphical user interface. The model currently contains five adjustable wave and current parameters, two adjustable sediment parameters, and two model parameters. Note that all numbers in the white boxes may be altered during the model runs. The 'restart' button starts the model from a grain size roughness random bed. The 'continue' button starts the model with the bed shown in the above graphic as the initial condition.